HIGH PRECISION EXTRAPOLATION METHOD IN DYNAMIC DOSING SYSTEMS BASED ON WEIGHT MEASURING PRINCIPLES

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A method and a technical solution are suggested in order to increase precision of worm-and-wheel dosing systems (bagging machines) operating on weight measuring principles. The results from the weight measuring are processed by using Fourier transformation and extrapolation of the weight transformation curve. The method is applied in an algorithm for controlling a flour-bagging machine.

1. INTRODUCTION

Dosing of bulk materials for production purposes is a very common process. Most dosing appliances and machines are based on indirect methods for mass measuring by accepting specific weight and bulk materials' flow as measured quantities. But these parameters influence the weight precision rather somewhat negatively.

In order to improve enterprise' competitiveness in a market economy the quality of products should be constantly increasing, and by extension productivity. In accordance to ISO 9001 for products' quality certification, one of the requirements is that precision in packaging should be constantly improved and controlled. The paper aims to improve precision in dynamic dosing of packaged (in bags) flour as well as to increase productivity requirements.

Some basic factors which influence batching are "deposing on walls", "the sinusoidal features of bulk flow during worm-and-wheel dosing", unequal humidity and different aerated indices of bulk materials, etc. Factors that alter slowly in the course of time (humidity) are compensated by a controlling algorithm. Other factors lead to serious errors in weight measuring (deposits of measured quantities), thus they should be identified and made evident by alarm indicators.

Decisive factors, which increase precision of dynamic measuring, are "determined deviations", which result from the sinusoidal law in worm-and-wheel feeding. Another is random distribution of flour specific gravity during dosing. Both characteristics must be taken into consideration.

The chart for batching and dosing bulk materials as shown in Fig. 1 includes a worm-and-wheel mechanism driven by an electric motor, weigh-measuring transformer, and a regulating unit for feeding and dosing. The regulator is a position regulator. Theoretically it is well known that best results for precision and quick action are achieved when a 5-sector speed diagram is used [1]. Conducted experiments show that different parts of the speed diagram can be optimized in order to increase precision [2].

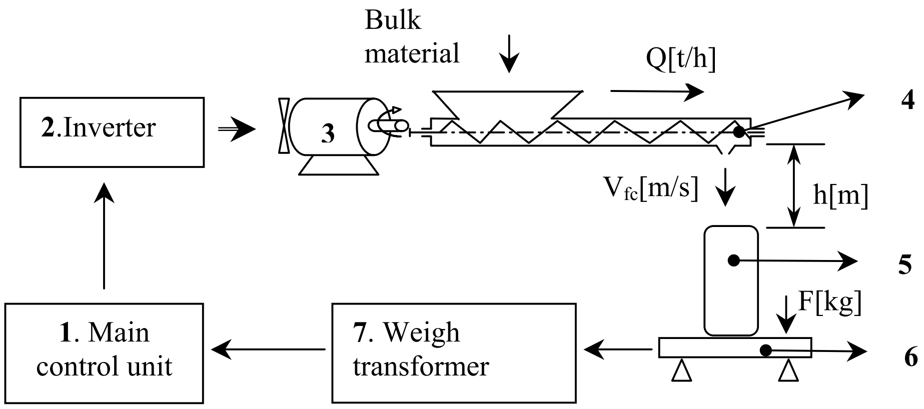

Fig. 1. Electronic system for dynamic dosing in worm-and-wheel mechanisms *1* - Main control unit*; 3* - Frequency control of the asynchrony electro motor*; 3* – 3-phase electro motor*; 4* - dosing worm-and-wheel mechanism*; 5* - Bag*; 6* – Tensometric system*;* *7* - Weigh transformer*;*

To achieve greater productivity one should apply higher speed by selecting a system with an inverter speed control with the main electro motor. The result is a relative error in the range 1.0%÷1.5%, which proves unacceptable for modern requirements of a relative error in dosing of ±0.2%.

2. DESIGNING THE PROCESS OF DYNAMIC DOSING

The material, which progresses through the worm-and-wheel system, is estimated in accordance to

$$\frac{dm}{dt} = \rho S L \omega, \qquad (1)$$

where ρ is the product's density; S – slice plane of worm-and-wheel system; L – tread's move; ω - rotation frequency of worm-gear.

The law which determines the change of the force F (t) on an electronic weight determining includes a quasi-static part equal to the product from the mass of the packaged (bagged) material and gravitation (m(t)*g), as well as a purely dynamic constituent part dependent on the free fall of the partial mass dm/dt onto the weigh from an altitude h, and all concludes with a velocity Vfc.=$\sqrt{2gh}$ for time $\tau=\sqrt{(2h/g)}$. The result

$$F(t) = m(t)g + \frac{dm(t)}{dt}\sqrt{2gh}\,, \tag{2}$$

shows that the measured force in a tensometric system is dependent on the influence of a falling mass from a given height. In other words – to determine the closing moment of the dosing one should consider the weight Mfc of the quantity falling down M= g*dm/dt * τ = dm/dt*√(2g*h) (3)

Concluding from (2) and (3) we can state that the weight of the falling material is equal to the dynamic constituent of the force exercised by the same product. Hence there is no need to prognosticate, respectively to figure out the moment when dosing finishes.

This is true under the condition dm(t)/dt=const, i.e. when above-mentioned factors aren't influencing the dosing process.

Dosing deviations emerging from different factors can be classified into determined and random (in time) ones. The determining constituent is mainly influenced by inaccuracies in different components of the dosing unit.

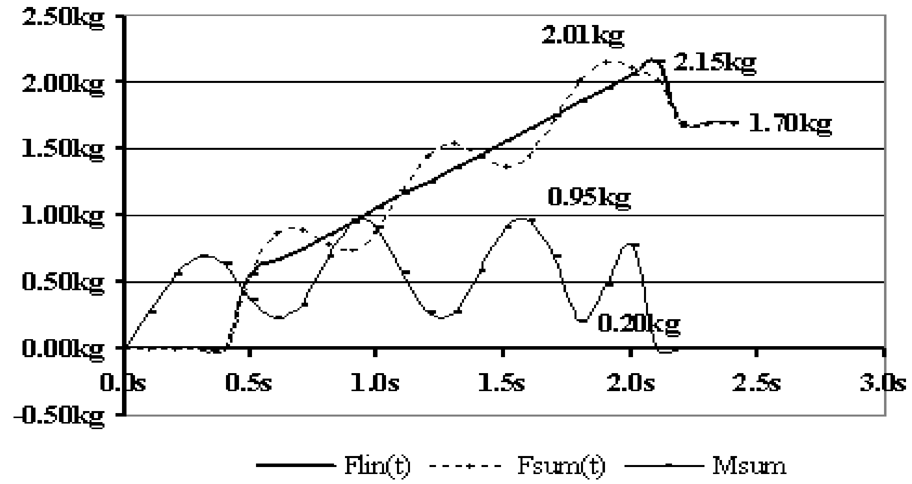

Fig. 2: Dynamic change of force on the tensometric system. Flin(t) – mathematical expectation of dynamic force; Fsum– tension by reading the influence of sinusoidal deviations in worm-and-wheel dosing; Msum – bulk material's weight by free falling.
dm/dt=1.0kg/s; h=1.0m; g=9.8m/s2; fm=5.2Hz;A=0.3kg; φ0=0°,τ=√(2h/g)=0.452sec

The same determining constituent could be permanent or periodic where the permanent constituent can be removed by using astatism in the controlling follow-up (procedure).

When dosing bulk materials the periodic constituent changes in accordance to the sinusoidal law:

$$\overset{*}{m}(t) = m_{stat}(t) + \hat{m}_{din}\sin(\omega t + \varphi_0) \tag{4}$$

From (2) and (4) we can determine the force exercised by the falling bulk flow onto the tensometric system:

$$F_{\Sigma}(t) = \overset{*}{F}(t) + \widetilde{F}(t) = \underbrace{m_{stat}(t)g + \hat{m}_{din}\sin(\omega t + \varphi_0 + \tau)}_{product\_in\_bag} + \underbrace{\sqrt{2gh}\,\frac{dm_{stat}(t)}{dt} + \hat{m}_{din}\cos(\omega t + \varphi_0 + \tau)}_{falling\_column} \quad (5)$$

The weight of the falling material is determined by

$$M_{\Sigma\, fc} = \overset{*}{M}(t) + \widetilde{M}(t) = \sqrt{2gh}\,\frac{dm(t)}{dt} + \int_0^{\tau} \hat{m}_{din}\sin(\omega t + \varphi_0)dt \quad (6)$$

From (5) and (6) the difference between the falling material and the dynamic constituent of the force on the tensometric system can be estimated as:

$$\Delta\widetilde{F}(t) = \widetilde{F}(t) - \widetilde{M}(t) = \hat{m}_{din}\cos(\omega t + \varphi_0 + \tau) + \hat{m}_{din}\,\frac{\cos(\omega\tau + \varphi_0) - \cos(\varphi_0)}{\omega}$$

$$\Delta\widetilde{F}(t) = \hat{m}_{din}\left(\cos(\omega t + \varphi_0 + \tau) + \frac{\cos(\omega\tau + \varphi_0) - \cos(\varphi_0)}{\omega}\right) \quad (7)$$

If we choose $\tau=2\kappa\pi/\omega$, then $\widetilde{M}(t)=0$. The initial phase φ_0 is a random one, but an indicator mounted on the worm-and-wheel mechanism could measure it. The constant value τ is dependent on the free fall of the bulk material from the height h, thus we can establish m_{din} by a Fourier transformation. $\widetilde{M}(t)$ isn't dependent on t, and if $\tau=2\kappa\pi/\omega$, $\widetilde{M}(t)=0$. $\Delta\widetilde{F}(t) = \hat{m}_{din}\cos(\omega t + \varphi_0)$. By increasing the rotation frequency ω of the worm-and-wheel mechanism, the sinusoidal constituent of the weight of the falling material $\widetilde{M}(t)$ is decreased. On the other hand the increased rotation frequency ω leads to an increased methodical error (9). Additionally one should note that constructional deficiencies of the worm-and-wheel mechanism add to the low-frequency fluctuations of the dosing material, something very undesirable.

Establishing the sinusoidal fluctuations (deviations) in the bulk material flow enables an extra polar stochastic and mathematical expectancy for a linear changing law by:

$$M(f) = f_0 + k * t \quad k = \frac{\dfrac{\sum_{i=1}^{n} f_i - f_0}{n} - \dfrac{\sum_{i=1}^{n/2} f_i - f_0}{n/2}}{t/2}, \quad (8)$$

where f_0- initial value of the force; f_i - momentarily values of the force, n – even number of measurements, and t – time, stand.

Fig 2 shows the graphic interdependence (5) and (6) for concrete values of the parameters.

CONCLUSIONS

- Exercised force during product packaging differs from its real "packaged" weight;
- A prognostic value should be set that halts the product's dosing from the worm-and-wheel mechanism;
- To quickly establish the harmonic amplitude one should apply a Fourier transformation;
- Random error can be evaluated by stochastic methods if the determining constituent is rejected first;
- Fig. 3 suggests an algorithm for applying the extrapolation method during dynamic dosing.

Measuring the tare-weight
1.Stochastic evaluation of tare-weight $M(F_{tare})=\sum F_{tare}/n$
2.Evaluation of tare-dispersion σreal<σmax

↓

Measuring during the dosing process
1.Extrapolation definition of m_{din} и φ_0 of sinusoidal deviations by applying Fourier analysis.
2.Extrapolation definition of dosing gradient.
3.Evaluation of gradient's dispersion
4.Estimating the closing moment of dosing.

↓

Measuring the dose
1.Stochastic evaluation of advance error
2. Evaluating the dispersion of dose measuring σreal<σmax

Fig. 3. Algorithm showing the discrimination of error in dynamic dosing by applying the extrapolation method

Tensometric system

In References [6] a gamma of transformers ANALOG DEVICES are shown for different application cases. We have chosen AD7730, which proved a universal one for dosing and weighing bulk materials. The transformation frequency f_t is determined by the probable methodical error $\varepsilon_m = \frac{dm(t)}{dt}\frac{1}{f_t}\frac{1}{M}$ (9)

Choosing a microcontroller

Control of dynamic dosing is highly dependent on the system’s behaviour. This requires a quick maintaining of stops (1) as well mathematical, stochastic and extra polation processing of results. Control of inverter requires maximum speed and high resolution. Some systems for quick communications have the possibility to control the inverter by using a serial channel. The use of a graphic display requires large resources of memory and productivity. The chosen processor is MC68HCS12DG256 and BDM debugger – USBMULTILINK. Some main features of MC68HCS12 are [4]: 20-bit ALU; min and max search; interpolation of graphics; “fuzzy” logics; high performance frequency (20 MHz), “Flash”, etc.

Above-mentioned method is first applied with the bagging machines of the Flour Mills in the towns of Razgrad and Blagoevgrad and in the village of Archar.

3. RESULTS

The method as described above increases productivity as well the precision in dynamic dosing.

- Machine’s productivity is increasing by 30 %;
- By applying the linear high precision extra polation method for evaluation of mathematical expectation of dynamic forces the standard error is decreasing by 50%;
- By applying Fourier’s transformation for evaluating the influence of sinusoidal deviations in dosing the error value is decreasing by 25%, thus making it very acceptable in terms of modern requirements to producers;
- Storage of process’ history by using a graphic display helps stochastic and extra polation evaluation of events with regard to measuring of dynamic forces.

4. CONCLUSIONS

The discussed method offers a very effective procedure for discriminating errors in dynamic dosing of bulk materials. It allows engineers to create modern dosing (bagging) machines and increase overall productivity. The proposed algorithm is based on stochastic and extra polation processing of measurements thus increasing their precision as well applying a factorial analysis on the influence of different construction and technological changes.

5. REFERENCES

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